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Cubomedusae (Cubozoa, Carybdeida, Carukiidae) in Hong Kong, China: first records of cubozoans in Chinese waters confirmed using citizen science and digital authentication

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Abstract. The Hong Kong Jellyfish Project uses photographs and videos from citizen scientists to document the occurrence of jellyfish in this region. Based on these records, we describe sightings of two previously unrecorded species of box jellyfish, *Malo filipina* (Bentlage & Lewis, 2012) and an unidentified species of *Morbakka* sp. Gershwin, 2008, in Hong Kong Special Administrative Region, China. This understanding of where these species currently occur is important due to the potential impacts of box jellyfish on human activities and their role in local ecosystems.

Keywords. Box jellyfish, range expansion, distribution, digital authentication

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Introduction

Confirming the occurrence and distribution of marine species will underpin our developing understanding of the biology and ecology of marine biota and address the urgent pressure to document marine species under increasing anthropogenic threats such as climate change (Gervais et al. 2021). However, marine taxonomic studies are hindered by challenges associated with collecting specimens, including logistical costs and safety issues in reaching the research location (Cigliano et al. 2015), quality of specimen preservation (Mitchell et al. 2021), and accuracy of data (e.g., morphological descriptions) for species identification (Thiel et al. 2014). Increasingly, citizen science and image analysis software serve as accessible and cost-effective tools for reporting species' occurrences (Thiel et al. 2014). Citizen science facilitated by social media is useful in the study of jellyfish distributions as it can be used to document organisms such as these with unpredictable appearances over large temporal and spatial scales (Gatt et al. 2018). With huge numbers of people engaged with online social networks, social media are natural extensions of citizen science outreach and participation platforms (Cranswick et al. 2022). Relevant online networks include those developed for citizen science specifically (e.g., Hong Kong Jellyfish Project, https://www.hkjellyfish.com/; Marine Conservation Society, https://www.mcsuk.org/what-you-can-do/citizen-science/sightings/jellyfish-sightings/), as well as more widely used platforms that are utilised to source citizen-science records (e.g., Instagram, Facebook). In these ways, social media can be a valuable tool for

recording observations of infrequently seen marine species (Cranswick et al. 2022). For example, by using a combination of website, social media, smart phone app, and email, the Spot the Jellyfish initiative in the Maltese islands received over 1000 reports of jellyfish between 2010 and 2017 and newly recorded the presence of five species from the area (Gatt et al. 2018). The use of social media to either actively or passively source ecological data can supplement and overcome some potential barriers to traditional monitoring efforts, such as limited funding and staffing (Cranswick et al. 2022).

Citizen scientists can contribute to reports of species' occurrence quickly and easily through the submission of photographs (Newcomer et al. 2019). There can, however, be issues associated with the use of such photographs. For example, in marine systems, divers may be limited in their ability to capture high-quality photographs of jellyfish due to variable environmental conditions (Gibbons et al. 2021). There are also biases in citizen-scientist photographic observations, such as choice of subject and geographical area, yet these observations still have value to researchers since photographs can provide information if the observed individuals can be identified to morphospecies (Gibbons et al. 2021). Where suitable photographs are obtained, image-checking software can be used to avoid the inclusion of manipulated images which have become more common as the use of editing software has become more widespread (Parveen et al. 2019). To date, much of the analysis of images in citizen science is in relation to the quality of photos for identification (Gould et al. 2021) or uses for machine learning to improve the speed of identification of large numbers of photos (Suzuki-Ohno et al. 2022). Within the context considered here, the use of image analysis in authentication of photographs submitted by citizen scientists is crucial to accurately identify taxa. For cubozoans in particular, as in this study, photographs have been used to identify them when specimens were not taken (Lawley et al. 2016).

Although a range of jellyfish have been recorded throughout the northwestern South China Sea (SCS) region (Table 1), records of box jellyfish in the academic literature for the region are lacking (but see, *Tripedalia maipoensis* sp. nov. Sun et al. 2023). Mostly thought of in the context of their stings, cubozoans can display mating behaviour not seen in other jellyfish (Lewis and Long 2005), have complex eyes that can be used for navigation (Garm et al. 2011), and display a strong swimming ability to maintain their location (Schlaefer et al. 2017). Their hunting, navigational ability, and courtship behaviours are thought to involve cognitive processing (Gershwin et al. 2013) not normally associated with other jellyfish. Despite these features, our understanding of the life histories, abundance, and distributions of the 50 described species of box jellyfish (Bentlage et al. 2010) is currently limited, in part because field observations and monitoring of them is restricted by large variations in abundance and their patchy dispersal

Table 1. Confirmed distribution of Medusozoa in northwestern South China Sea.

Locality	Class	*Species*	Reference
Southeastern China	Hydrozoa	*Aequorea macrodactyla*	Xia et al. 2002
Off Hong Kong	Hydrozoa	*Corymorpha brunnescentis* (Huang, 1999)	Huang 1999
Off Hong Kong	Hydrozoa	*Eirene hexanemalis* (Goette, 1886)	Kramp 1953
Dongsha Island	Hydrozoa	*Obelia bidentata*	Yan et al. 2009
	Hydrozoa	*Obelia dichotoma*	Yan et al. 2009
Southeastern China;	Hydrozoa	*Protiaropsis minor* (Vanhoffen, 1911)	Vanhöffen 1911
Near Hong Kong			Kramp 1953
Xiamen, China	Scyphozoa	*Acromitus flagellatus*; *A. maculosus*	Maas 1903; Jarms and Morandini 2019
Xiamen, China	Scyphozoa	*Acromitus tankahkeei*	Light 1924
Southeastern China	Scyphozoa	*Anomalhoriza shawi*	Ricca and Cheung 2021
Hong Kong	Scyphozoa	*Aurelia aurita*	Morton and Morton 1983; Liu 2008
Southeast China;	Scyphozoa	*Cyanea nozakii*	Chen 1982
Hong Kong	Scyphozoa		Liu 2008
Southeastern China	Scyphozoa	*Lobonemoides gracilis*	Hong and Lin 2010
	Scyphozoa	*Mastigias ocellatus*	Modeer 1791; Kramp 1961
Liadong Bay, China	Scyphozoa	*Rhopilema esculentum*	Omori and Nakano 2001; Dong et al. 2010
Liadong Bay, China	Scyphozoa	*Rhopilema hispidum*	Vanhöffen 1888; Kramp 1961
Hong Kong	Scyphozoa	*Thysanostoma loriferum*	Terenzini and Falkenberg 2022
Beibu Gulf	Scyphozoa	*Versuriga anadyomene*	Sun et al. 2018
Hong Kong	Cubozoa	*Tripedalia maipoensis*	Sun et al. 2023
Hong Kong	Cubozoa	*Malo filipina*	This study
Hong Kong	Cubozoa	*Morbakka* sp.	This study

(Kingsford and Mooney 2014). The range of some cubozoan populations can be from hundreds of meters to hundreds of kilometres, though within a species' range the smaller local populations may be more discrete with limited connectivity (Kingsford et al. 2021). Within the box jellyfish group, members of the family Carukiidae Bentlage, Cartwright, Yanagihara, Lewis, Richards & Collins, 2010 are thought to be distributed throughout the tropical to temperate waters of the Indo-Pacific, from New South Wales, Australia to Honshu, Japan; however, the longitudinal boundaries of this family's geographic range are not known (Bentlage and Lewis 2012). These distribution patterns may change in the future as a consequence of anthropogenic stressors including climate change (Klein et al. 2014; Pitt et al. 2018), so understanding the current distribution is key to establishing a baseline from which to consider potential future changes.

Here, we describe observations and records of box jellyfish, specifically carybdeid medusae, in the northwestern SCS region (Hong Kong) from photographs and videos provided by citizen scientists undertaking recreational dives. This is the first report of species of *Morbakka* and *Malo* in the academic literature of box jellyfish in waters of southeast China, and more specifically Hong Kong.

Methods

The Hong Kong Jellyfish Project (HKJP) (https://www.hkjellyfish.com) is a citizen-science project which is successfully studying local jellyfish presence by collecting citizen-science sightings of jellyfish in Hong Kong waters (Terenzini and Falkenberg 2022; Terenzini et al. 2023). Anyone in Hong Kong can participate in the HKJP by filling in an online form with simple data (date, time, location, number of jellyfish) and submitting photographs or video of jellyfish seen during observers' daily lives or water-based activities. Social media on Instagram and Facebook groups are also manually monitored for jellyfish sightings in Hong Kong.

Details were obtained of two cubomedusae observations reported through the HKJP website and social media. A carybdeid jellyfish with prey fish was photographed by a local scuba diver on 5 June, 2021 at a depth of 10 m with ambient water temperature of 23 °C near Trio Island, Hong Kong. On 14 September 2022 another carybdeid cubomedusa with nematocyst warts was photographed and video recorded at 8–10 m depth and 28 °C ambient water temperature at Ninepin Island, Hong Kong. Original copies of photographs (photos of observation 1 in 2021: $n = 9$; observation 2 in 2022: $n = 23$) and videos (observation 2 in 2022: $n = 2$), and the details of their acquisition such as model of camera used, depth and time of their capture, were requested and received by the HKJP by email.

The photographs were assessed for authenticity and traces (or absence) of editing through several methods and software. The images of cubozoans were matched to other visually similar images online such as photos of box jellyfish using Dupli Checker (https://www.duplichecker.com), which contains several reverse image engines (e.g., TinEye engine). Markers of image compression and metadata of exchangeable image file format (EXIF) of the images were analysed in JpegSnoop, an online freeware that extracts image metadata such as EXIF, image marker (e.g., APP1), and thumbnail details (e.g., thumbnail format and widthbytes) (Parveen et al. 2019). The freeware detects the quality and nature of the image compression used by the camera in saving the file and history (or absence) of editing of images (Bedi et al. 2020; Gangwar and Pathania 2020; Zhang and Wang 2015). Endian details or the system of ordering bytes in the saved information of the images were also examined. Error-level analysis (which indicates different textures in image pixels) and analysis of pixel condition (e.g., presence of transparent pixels overlaid on the visible image) of the photographs through the 'hidden pixels' function were conducted in Fotoforensics (Krawetz 2015; Parveen et al. 2019). The videos were analysed for authenticity using VideoCleaner (Supplemental files Fig. S1; http://videocleaner.com) (Javed et al. 2021). The software has Video Error Level Analysis (VELA) function that detects content cropping or alterations, and tampered content as inconsistent brightness or colour, when compared to other video scene details of similar contrast (Carner 2019; Javed et al. 2021). The VELA was done by activating the VELA function under the 'Analysis and Information' tools (Carner 2019). The brightness, contrast, sharpness, curve lighting balance and equalizer functions (Fig. S1) were adjusted to detect potential tampering of video frames.

We identified the jellyfish using morphological features (e.g., pedalial canal) visible in the images and videos (as in Ford et al. 2020; Terenzini and Falkenberg 2022). When necessary, the contrast, brightness, and focus (including magnification) on the images were adjusted to confirm if the features visible to the naked eye were indeed morphological parts of the cubomedusae, rather than photographic artefacts like reflection or light scattering that can look like body parts of jellyfish (see Farid 2019). In the identification, we used the descriptions and images of jellyfish by Bentlage and Lewis (2012), Gershwin (2008), Jarms and Morandini (2019), Kishinouye (1910), Mayer (1910), Southcott (1956), and Straehler-Pohl (2014). When family taxon of our cubozoans was identified, our medusae were also compared to photographs of live cubomedusae such as carybdeids *in situ* from the type locality of *M. filipina* (i.e., *M. filipina* and *Alatina* sp. in Batangas, Philippines), live *M. filipina* (Sho Toshino's identification, page 711) in Jarms and Morandini (2019), *Carybdea prototypus* (synonym: *Carybdea brevipedalia*) of Shirahama, Japan (A. Migotto obs., http://cifonauta.cebimar.usp.br/media/3004), *Tamoya haplonema* of Brazil (A. Migotto obs., http://cifonauta.cebimar.usp.br/media/2983), *M. maxima* of Australia (including J. Strickland obs.,

https://www.inaturalist.org/photos/254518301) and live medusae of *Morbakka* spp. (i.e., *M. virulenta* by Sho Toshino, and Okinawa Institute of Science and Technology, Japan and *M. fenneri* by Merrick Eckins, Queensland Museum, Australia).

Here, estimates of sizes (bell width and height) of the cubomedusae by the divers satisfy the requirements in estimating sizes of marine fauna like highly mobile fish juveniles in visual census surveys (Wilson et al. 2018). The requirements include the close distance (<1 m) between the diver and cubomedusae during field observations, known size estimates (relative to the size of the cubomedusae here) of other objects near the subject cubomedusae (e.g., plankton larvae or finger or hand of divers), and, importantly, the divers' experience (i.e., >5 years) in estimating sizes of objects during scuba diving (French et al. 2021; Wilson et al. 2018).

Results

Order Carybdeida
Family Carukiidae

Malo filipina (Bentlage & Lewis, 2012)

New record. CHINA – **Hong Kong** • Trio Island; 22°18′06.0″N, 114°19′04.6″E; 10 m depth; 5.VI.2021; Calvin Tang obs.; 1 individual, sex undetermined.

Identification. The individual of *M. filipina* (photographed in 2021; Fig. 1) had a bell height of 3 cm and width of 2.5 cm. The size of the pedalia is about one-third the height of the bell. The exumbrella is covered in deep red warts (Fig. 1A), and the tentacles are cylindrical with yellowish pearl to ring-like bands; both of these are characteristic of *M. filipina* (Fig. 1A). The rhopalar niche opening is frown-shaped, a feature of *Malo* spp. (Fig. 1A, J). The Cubomedusa is similar to Philippine *M. filipina* with deep-red nematocyst warts and without gastric phacellae, but unlike *Carybdea prototypus* (Fig. 1C) and Philippine *Alatina* sp. (Fig. 1A, D) which have gastric phacellae and small, white to opaque nematocyst warts. The velarial canals are branched, palmate to digitiform, and with three or four canal roots per velarial octant (Fig. 1E, F), like the form of three velarial canals per octant of Philippine *M. filipina* (Fig. 1G, H) The velarium of the photographed individual is unlike that of *Malo* spp. from Australia (*Malo bella* nomen dubium and *M. maxima*) which have more than four velarial canal roots per octant. The frenulum is thick and without a "split" (Fig. 1I). The rhopalium has short, blunt-tipped rhopalar horns and a frown-shaped niche ostium (Fig. 1J). The perradial lappet is triangular and with four large nematocyst warts on either side of the lappet (Fig. 1K). The pedalial canal is smooth in its upper quadrant (Hong Kong and Philippine *M. filipina*; Fig. 1L, M) unlike the upper pedalial canal of Australian *Malo maxima* which has ridges instead. The pedalial canal bend bears an elongated to thorn-like extension, typical of *M. filipina* (Fig. 1L, M). Most nematocyst warts are on the abaxial (outer) keel, and the inner keel has a distal overhang (Fig. 1L, M).

Morbakka sp.

New record. CHINA – **Hong Kong** • Ninepin Island; 22°15′36.7″N, 114°20′56.0″E; 8–10 m depth; 14.IX.2022; Kevin Leung obs.; 1 individual, sex undetermined.

Identification. The individual of *Morbakka* sp. (recorded in 2022; Fig. 2) had a large, wart-covered bell (Fig. 2A) with a bell height of 20 cm; it is within the body size range of *Morbakka*. The flat, ribbon-like tentacles are 100–120 cm long. The box shape of the body and single tentacle from each pedalium are characteristic of the order Carybdeida (Fig. 2A). The absence of gastric phacellae, a visible pedalial canal that flares towards the tentacle attachment, and the large spike on the pedalial canal knee bend are characteristics of *Morbakka* (Fig. 2A). The medusa is unlike *Tamoya* spp., which have prominent vertical gastric phacellae (Fig. 2B). The shape of the rhopalar niche and horns "match" the rhopalar niche of *M. virulenta* in which the rhopalar horns are positioned at a low angle (19–20°) and originate from the upper centre of rhopalar niche and frown-shaped ostium, and which prominently reveal the rhopalium (Fig. 2C). The frenulum is thick, "splits" near the rhopalar niche, and extends to the centre of the perradial lappet (Fig. 2D); the triangular lappet has large nematocyst warts unlike the warts surrounding the lappet (Fig. 2D). There are between seven and nine nematocyst warts on either side of the lappet, which are prominently large (Fig. 2D) compared to warts surrounding the lappet (Fig. 2A, D). Nematocyst warts are nearly evenly to evenly distributed on the exumbrella, although there are elongated warts on the outer pedalial "wing" (Fig. 2A, G). The gastric mesentery is well developed and the manubrium has smooth tips (Fig. 2E). Velarial canals are dendritic (Fig. 2A, F). The pedalial canal has a thorn-like extension of the pedalial canal bend, the outer "wing" bears elongated nematocyst warts, and there is an inner keel, which is smooth and with an overhang as in *M. virulenta* (Fig. 2G).

Image authentication. The photographs did not match any images of cubomedusae on the internet. EXIF and marker details of the images were different between the images of the two species, but not between images of each species (Fig. S2). Canon EOS and Olympus digital cameras were used to document *M. filipina* and *Morbakka* sp., respectively, and these details match the divers' claims about the equipment used to photograph the cubomedusae (EXIF results; Supplemental file Fig. S2). Endian details (definition in the Methods) in the APP1 markers did not vary, and the thumbnail information is present in the images of *M. filipina* only. The time and dates the images were captured do not match the time and date of potential editing in all images. APP0 marker did not appear in the metadata of the images (Supplemental file Fig. S2). Textures of the images were consistent (ELA; Supplemental file Fig. S3), and hidden pixels were absent (Supplemental file Fig. S3). In the

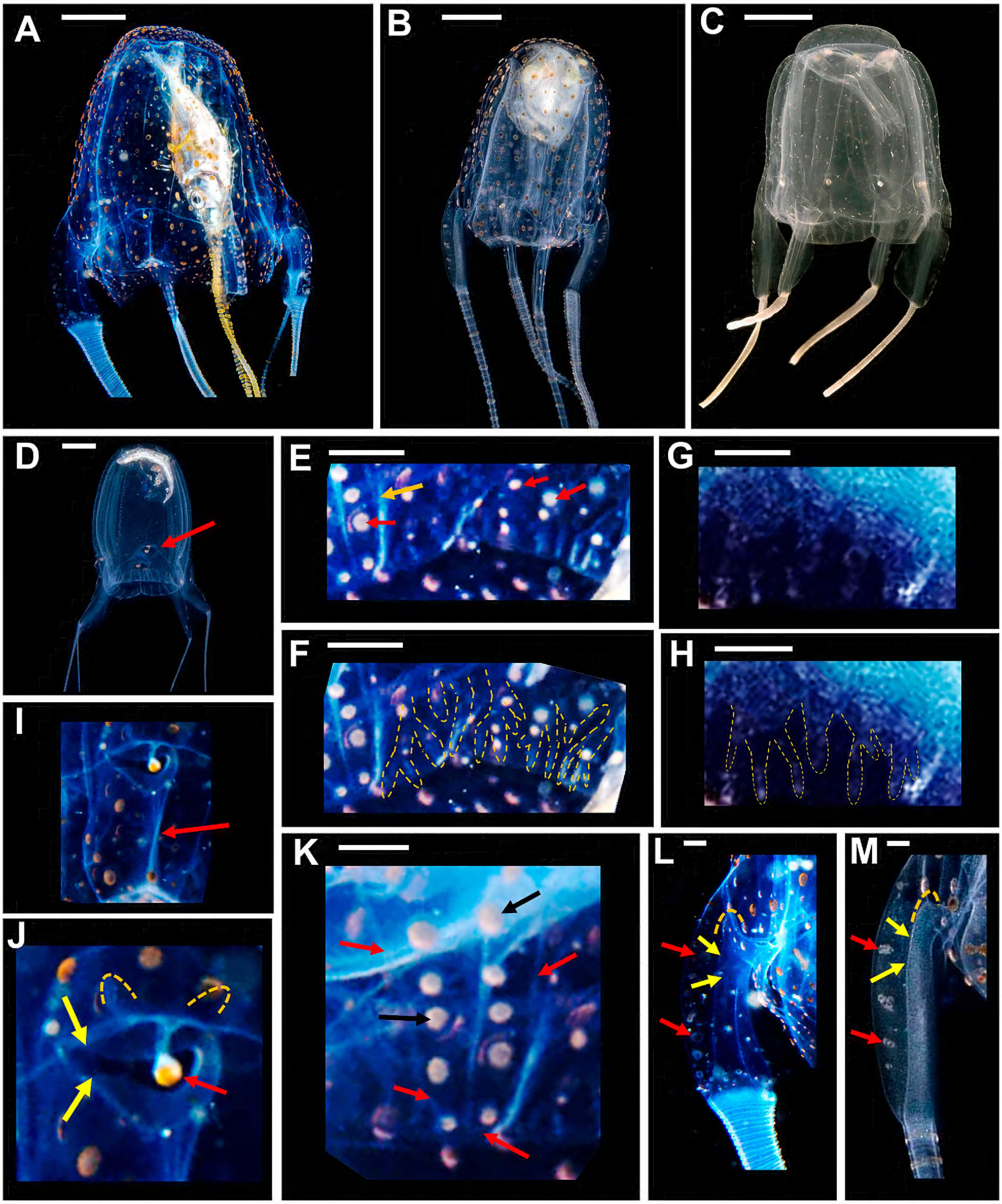

Figure 1. Identifying characteristics of *Malo filipina*. **A.** Cubomedusa with deep red colored nematocyst warts in Hong Kong. **B.** Medusa of *Malo filipina* in Batangas, Philippines. **C.** Live *Carybdea prototypus* (synonym: *C. brevipedalia*) with visible rhopalium and velarial canals. **D.** Medusa of *Alatina* sp. *in situ* in Batangas, Philippines with T-shaped rhopalar niche ostium (red arrow). **E, F.** Velarial octant with velarial canals of Hong Kong *M. filipina*: (**E**) red arrows point nematocyst warts; yellow arrow shows perradial lappet; (**F**) yellow dashed lines emphasize the velarial canals). **G, H.** Velarial octant of the Philippine *M. filipina* with palmate canals (yellow dashed lines for emphasis). **I.** Thick frenulum under rhopalium. **J.** Rhopalium (red arrow) with visible rhopalar covering (yellow arrows) (yellow dashed lines emphasize short and blunt-tipped rhopalar horns). **K.** Perradial lappet with edges (red arrows) and the two "columns" of the nematocyst warts (black arrows) of the lappet. **L, M.** Pedalial canals of *M. filipina* in Hong Kong (**L**) and the Philippines (**M**) with smooth upper quadrant (yellow arrows), thorn-like extension of pedalial canal bend (yellow dashed lines) and more prominent nematocyst warts (red arrows) of the outer "wing" of pedalium. Scale bars: A–C = 10 mm; D = 20 mm; E, F = 1mm; G, H, K–M = 2 mm. Photos courtesy of Calvin Tang (A, E, F, I–L), Claudio Ceresi (B, G–H, M), Alvarro Migotto (C), Andrew Minxiong (D).

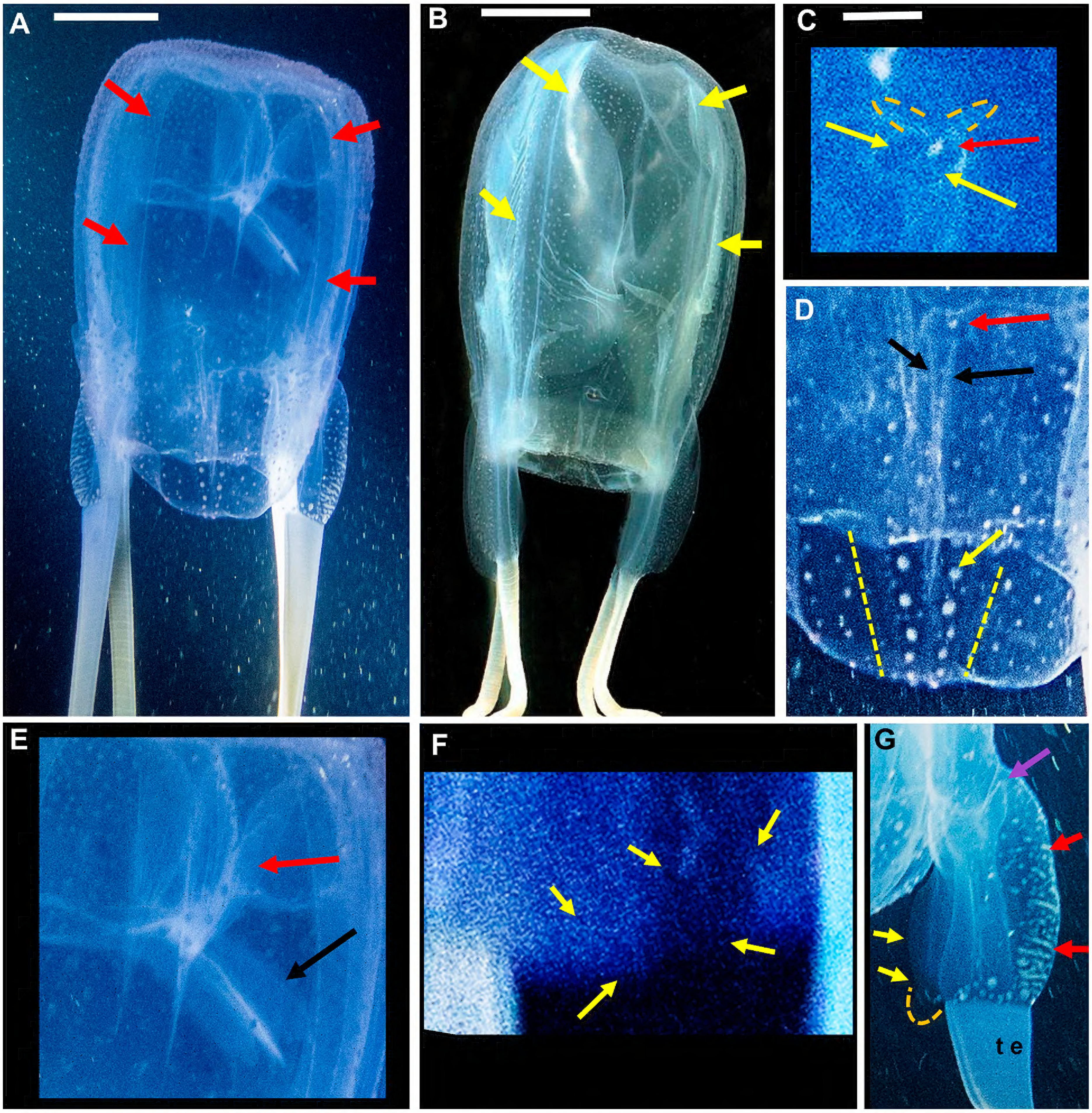

Figure 2. Characteristics of *Morbakka* sp. **A.** Large, wart-covered bell with four flat, ribbon-like tentacles extending from four pedalia and smooth gastric area without phacellae (red arrows). **B.** Live *Tamoya haplonema* with multiple vertically positioned gastric phacellae (yellow arrows). **C.** Rhopalium of *Morbakka* sp. in Hong Kong with rhopalar horns originating from the upper centre of rhopalar niche (dashed lines) (yellow arrows show covering of rhopalar niche). **D.** Frenulum with "split" (black arrows) near the rhopalar niche and triangular lappet with "columns" of large nematocyst warts (yellow arrow) (dashed lines emphasize edges of the lappet). **E.** Gastric area of medusa here with well-developed mesentery (red arrow) and manubrium with smooth "lips". **F.** Velarial octant with dentrite-shaped canals (yellow arrows). **G.** Pedalial canal with thorn-like tip of the pedalial canal bend (purple arrow), outer keel with elongated nematocyst warts (red arrows), and smooth inner keel (yellow arrows) with an overhang (dashed line) (te = tentacle). Scale bars: A = 5 cm, B = 4 cm, C = 5 mm. Photos courtesy of Kevin Leung (A, C–G), Alavarro Migotto (B).

videos, we did not detect cropped and sharpened pixels, and the resolution and contrast of pixels are even in each frame.

Discussion

Citizen science is increasingly used worldwide to collect data on species that are difficult to find (Feldman et al. 2021). The "many eyes hypothesis" of citizen science means that large numbers of participants can generate useful data across larger geographical and temporal scales than would be possible by individual researchers, increasing the chances of detection of rare, invasive, or sporadically occurring species (Earp and Liconti 2020). Here, we identify and confirm the occurrence of cubomedusae of *M. filipina* and an unidentified species of *Morbakka* sp. using citizen-science field observations, and graphically authentic photos and videos. Our results are evidence of the benefit of using authenticated records which show the appearance of the cubomedusae *in situ*. This approach could potentially rival the

quality of morphological information of jellyfish that we can obtain from preserved specimens that have lost live coloration and texture.

This report extends the latitudinal record of *M. filipina* approximately 1000 km from its known type locality (i.e., Nasugbu, Luzon) and distribution in the northwestern Philippines (Fig. 3) (Bentlage and Lewis 2012; Jarms and Morandini 2019). Jellyfish in the order Carybdeida, such as *Malo* spp., can be identified from the single tentacle at the pedalium from the corners of the bell (Straehler-Pohl 2014). *Malo filipina* can be identified by the colour of the warts on the bell, the colour and shape of the tentacles (Jarms and Morandini 2019), the number of velarial canals per octant, and the shape of the pedalial canal knee bend (Straehler-Pohl 2014). Specifically, the deep-red warts on the exumbrella are a notable feature of *M. filipina*. Among box jellyfish, *M. filipina* is one of the smaller species, with a bell height to 4 cm and a bell width to 3 cm (Jarms and Morandini 2019), placing our carybdeid records here within the size range of *Malo* spp. While there are other similarly sized carybdeid jellyfish, such as *M. maxima*, they can be distinguished by their tentacular cnidomes and the shape of the pedalial canal (Bentlage and Lewis 2012). Specifically, *M. filipina* has a spike at the pedalial canal bend (which was observed here), which *M. maxima* does not have (Bentlage and Lewis 2012).

There are two recognized species in the genus *Morbakka*; *M. virulenta* (Kishinouye, 1910) found in the waters around Japan, and *M. fenneri* (Gershwin, 2008) found around eastern Australia. *Morbakka* spp. have also been found in the waters of the Philippines (Bentlage and Lewis 2012), Malaysia (Rizman-Idid et al. 2016), and Singapore (Iesa and Yap 2018) (Fig. 3). The morphological differences between *M. virulenta* and *M. fenneri* are in the rhopalar horns and nematocyst warts, which are not readily apparent in the citizen-scientist photographs reported here, so we are not able to identify this individual to species. Additional observations of *Morbakka* sp. have also been reported to the HKJP, although the light conditions or distance from the subject mean they are not able to be analysed for fine-scale details. However, they do substantiate the presence of additional cubomedusa in Hong Kong waters. Specifically, one observation was made on 21 December 2022 at Lantau Island, Hong Kong, and another taken on 26 December 2022 at So Kwu Wan fish farm at Lamma Island, Hong Kong (Fig. 4).

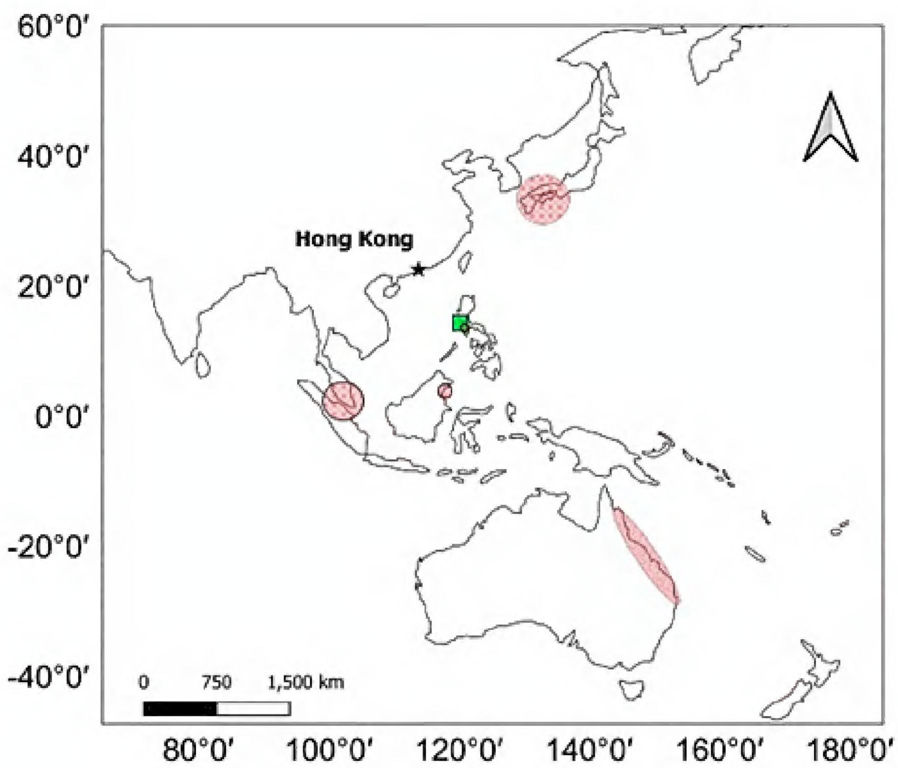

Figure 3. Species distribution for *Malo filipina* (green square) and *Morbakka* spp. (red ovals). Hong Kong (star) is the location of the sightings reported here.

Factors that may influence the occurrence of these carybdeids in the northwestern SCS include the distribution and settlement of planula larvae of cubozoans and the distribution of their prey. For example, currents in the northern SCS (including the Kuroshio Current Intrusion) which move along the distribution area of cubozoans in the region (Liu et al. 2013; Jarms and Morandini 2019), may transport larvae of the carybdeids along coastal areas surrounding the northern SCS. The larvae may survive transport over these distances, as they can survive for few hours or several days (up to ~9 days) before settling into polyps (Toshino et al. 2013; Underwood et al. 2018). Notably, the larvae and juveniles of anchovies *Engraulius* spp., jack mackerel *Trachurus* spp., and rabbitfish *Siganus* spp. occur in

Figure 4. Additional *Morbakka* sp. observations in Hong Kong. **A.** Video still taken on 21 December 2022 by Pettythings **B.** Single photograph taken on 26 December 2022 by Ocean Lee.

Hong Kong (Sadovy and Cornish 2000). These fishes are prey items of *M. virulenta* (Kondo et al. 2018) and *M. filipina* (Lewis and Macrander 2016). We advocate for examination of cubozoan larval transport and prey distributions in future studies considering the mechanisms underlying the distributions of cubozoans in this region.

Here, cubomedusae were reported to the HKJP through social media-based citizen-science platforms by local divers who shared photographic and video documentation. Without this avenue, these species would likely remain undocumented, as there is no active field monitoring or collection of specimens of cubomedusae for taxonomy in the region. The ability of citizen scientists to contribute to taxonomy has been enhanced by the widespread use of smartphones and other technology that allows for increased photographic contributions and correct identification of species (Ditria et al. 2020; Garcia-Soto et al. 2021). Although there can be concerns about the quality and accuracy of contributions from citizen scientists, these concerns can be alleviated with sufficient attention to study design and data verification (Earp and Liconti 2020), with image and video verification enabled by software such as those used in this study (e.g., DupliChecker, JpegSnoop, Fotoforensics, VideoCleaner). The use of online citizen-science platforms such as iNaturalist for biodiversity data collection can have taxonomic biases towards larger species that are easier to see and geographical biases towards higher-participation areas like Europe and North America. However, with targeted outreach to underrepresented areas such as Asia and Africa, and efforts by scientists to mitigate known biases, citizen-science data can provide valuable data when integrated with the published literature (Anthony et al. 2023).

Compared to preserved specimens, digital records capture important colours and textures which are useful in the diagnosis and confirmation of many plant and animal species (Fritz and Ihlow 2022). The combination of colours and textures with other diagnostic characters visible in digital records enable the confirmation of new species and even the level of dispersal of invasive species, for example, the ladybird *Harmonia axyridis* in central America (Hiller and Haelewaters 2019). Indeed, confirming the occurrence of the chirodropid box jellyfish, *Chironex* sp. on deep reefs of Western Australia (Keesing et al. 2016) and identifying a new species of ctenophore (*Duobrachium sparksae*) from a depth of ~3,910 m off Puerto Rico (Ford et al. 2020) would not have been possible without photographs and videos capturing live conditions of the animals from relatively inaccessible habitats. While there can still be a need to obtain preserved specimens, as per the International Commission of Zoological Nomenclature, where authenticated and high-quality images and videos are available, as was the case in this study, they can be helpful tools in identifying species.

Here, box jellyfish were recorded for the first time in Hong Kong with their occurrence having potential implications for humans in the region. The nearshore areas that many box jellyfish prefer, and in which they were observed, overlap with the areas in which humans undertake recreational activities, potentially endangering human safety because of the potential for stings (Crow et al. 2015). The sting of *Malo filipina* has not been studied in detail, but it is thought to be comparable to *M. maxima* (Jarms and Morandini 2019), one of the jellyfish able to cause Irukandji syndrome (Carrette et al. 2012). Irukandji syndrome is a debilitating condition with symptoms ranging from pain and hypertension to heart problems, and even pulmonary or cerebral edema (Carrette et al. 2012). Where stings have not been recognized, they have caused deaths (Bouyer-Monot et al. 2017). Additionally, the stings of the two recognized species of *Morbakka* are thought to be severe to life threatening (Jarms and Morandini 2019). In Hong Kong, the Hospital Authority (HA) does not stock jellyfish antivenom and jellyfish stings are not recorded (personal communication with HA Head Office), so records of box jellyfish from Hong Kong waters are important for understanding risks to human health. There are economic impacts of jellyfish stings and Irukandji syndrome on tourism-dependent economies, as tourists avoid areas with reported stinging jellyfish, and there are also political impacts, as local governments differ in their management strategies for dealing with potentially deadly jellyfish (Gershwin et al. 2010). Therefore, we must understand the distribution of box jellyfish species in order to better inform management of potentially harmful species (Kingsford and Mooney 2014).

Conclusion. The sightings presented in this report are the first of the box jellyfish species of *Malo* and *Morbakka* within Hong Kong waters and northwestern SCS. Notably, they were obtained via a citizen-science project, the HKJP. While caution should be applied to the use of citizen-science photographs and videos as the sole means of identification of species, the benefits of citizen science to discovering difficult to find or episodic marine species such as many jellyfishes are well known and, again, evidenced here. Verification of photographs through available image-checking resources such as DupliChecker is recommended to ensure trust in and accuracy of data. More follow-up research is needed into the ranges of potentially harmful species such as box jellyfish in order to better inform their ecology and management. The potential impacts on human activities and their roles in ecosystems, from new species or shifting ranges of species, should be examined further to obtain better ecological understanding of box jellyfish species and enable informed policy decisions with regard to their impacts to society.

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Author Contributions

Conceptualization: JT, LJF. Data curation: JT. Formal analysis: JT, SRB. Funding acquisition: LJF. Investigation: JT, SRB. Methodology: JT. Project administration: JT. Software: JT. Supervision: LJF. Validation: SRB. Visualization: JT, SRB, LJF. Writing – original draft: JT, SRB, LJF. Writing – review and editing: JT, SRB, LJF.

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Supplemental Files

Figure S1. Graphical interface of VideoCleaner software.
Figure S2. Marker and EXIF analysis results of the cubozoan images.
Figure S3. Compression and pixel analysis results of the cubozoan images.